

AUDIT OF PRE HOSPITAL PAEDIATRIC RESUSCITATION

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PLAGIARISM DECLARATION

I, Abraham Jacobus Coetzee, (Student number: 774484) am a student registered for the degree of Master of Science in Medicine (Emergency Medicine) in the academic year of 2019 at the University of the Witwatersrand, Johannesburg.

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DEDICATION

I dedicate this study to honour my Creator and Saviour, my Father who lives in heaven, who has given me the ability and opportunity to pursue and complete this degree.

I further dedicate this work to my dear loving wife, Siedine and two sons, Andrieu and Matheu for their sacrifice, continual support and encouragement to its completion.

This study is also dedicated to the silenced laughter and the left behind bereaved.

"Think of your child then, not as dead, but as living; not as a flower that has withered, but as one that is transplanted, and touched by a Divine hand is blooming in richer colours and sweeter shades than those of earth."

Richard Hooker, British theologian

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PUBLICATIONS ARISING FROM THIS STUDY

No publications have yet arisen from this study. It is the author's intention to submit a paper to a peer-reviewed journal upon successful completion of this degree.

List of Abbreviations

ABC	airway breathing circulation
AED	automated external defibrillators
AHA	American Heart Association
ALS	advanced life support
ANA	ambulance emergency assistant
BAA	basic ambulance assistant
BHF	Board of Healthcare Funders
BLS	basic life support
CA	cardiac arrest
CAB	Circulation airway breathing
CCA	critical care assistant
CPR	cardiopulmonary resuscitation
ECA	emergency care assistant
ECP	emergency care practitioner
ECT	emergency care technician
EMS	emergency medical services
HPCSA	Health Professions Council of South Africa
ILCOR	International Liaison Committee on Resuscitation
ILS	intermediate life support
IO	intraosseous
IV	intravenous
Kg	kilogram
NQF	National Qualification Framework
MVA	motor vehicle accident
min	minute
OECO	operational emergency care orderly
OR	odds ratios
PALS	paediatric advanced life support
PBEC	Professional Board for Emergency Care
PEA	pulseless electrical activity
ROSC	return of spontaneous circulation
SA	South Africa

SAPAESA South African Private Ambulance and Emergency Services Association
VF ventricular fibrillation
VT ventricular tachycardia

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Abstract

Introduction: Survival after paediatric pre-hospital cardiac arrest (CA) remains low at 4-13%. Research confirms that certain non-modifiable and modifiable factors of CA are associated with the return of spontaneous circulation (ROSC). However, no such study has been conducted in the African context.

Methods: A retrospective descriptive audit was performed on all paediatric patients that received cardiopulmonary resuscitation (CPR) at a private South African Emergency Medical Services (EMS) agency (n=195) from 1 January 2011 until 1 January 2015. Non-modifiable and modifiable factors of CA were captured on an Utstein-style reporting template and the association with ROSC calculated.

Results: Regarding non-modifiable factors, the majority of the cases were among males (n=122; 62.6%), aged 6-12 years (n=57; 29.2%) with the initial rhythm of asystole (n=104; 53.3%). Most of the cases were medical as opposed to trauma - related (n=130; 66.7%), of which drowning was the most common aetiology (n=62; 31.8%). Regarding modifiable factors, 21.5% of the cases were EMS witnessed. Bystander CPR prior to EMS arrival was initiated in 44.6% of the cases. The most common intervention provided by EMS was advanced airways (n=152; 77.9%), administration of adrenaline (n=151; 77.8%), intravenous access (n=113; 58.5%) and defibrillation (n=22; 11.3%). Transportation to the emergency department occurred in 45.1% of the cases, and ROSC was achieved in 42 cases (21.5%). An initial rhythm of Pulseless Electrical Activity (odds ratio=4.58; 95% CI 1.97-10.64) was the only non-modifiable factor, and bystander CPR (odds ratio=2.16; 95% CI 1.08-4.33) was the only modifiable factor significantly associated with ROSC.

Conclusion: Prevention is the most effective way to avoid deaths in paediatrics. In this study, the only modifiable factor of CA was bystander CPR, highlighting that more should be done to raise the awareness and skills of citizens in the performance of basic life support.

Introduction

Pre-hospital cardiac arrest (CA) affects thousands of children globally each year [1]. Survival following out-of-hospital CA is most significant in paediatrics [2, 4], but even then, only 4-13% of children will survive to hospital discharge with favourable neurologic outcomes [4, 8].

Several studies have shown that gender [9, 11], age [2,7,9], aetiology [9,12,13] and initial rhythm [2,9,14] are non-modifiable factors of CA associated with return of spontaneous circulation (ROSC) and increased survival in paediatric patients. Modifiable factors of CA associated with ROSC include EMS witnessed arrest [10,11,15], bystander cardiopulmonary resuscitation (CPR) prior to EMS arrival [16, 18], airway management [1,7,19,20], vascular access [7,21,22], defibrillation [7,17,23], drug administration [2,24,25], emergency medical service (EMS) arrival time, EMS scene time, and EMS transport time [7,16,26,27].

The importance of these non-modifiable and modifiable factors on ROSC and increased survival in paediatric patients has been studied in North America [1,7], Europe [9,28], Asia [16] and Australia [13]. However, as far as is known to the authors, no similar study on pre-hospital paediatric resuscitation has been conducted in Africa. Therefore, the aim of this study was to conduct a retrospective descriptive audit of paediatric CA patients in a private South African EMS agency, in an attempt to establish the association between non-modifiable (gender, age, aetiology and initial rhythm) and modifiable (witnessed arrest, bystander CPR, airway management, vascular access, defibrillation, drug administration, EMS arrival time, EMS scene time, and EMS transport time) factors of CA and its association with ROSC.

Methods

Design

A retrospective descriptive audit was performed on the paediatric patient database of a South African private EMS agency.

Patient Population

Data for all paediatric patients from 1 January 2011 until 1 January 2015 who received CPR at the selected national private EMS agency were included in this study population (n=195). The EMS in South Africa functions in a two-tiered system, where the public sector (83% of the population or 47 million people) primarily provides medical care for patients without a medical aid or the uninsured, and the private sector (17% of the population or 9.5 million people) provides medical care for those with medical aid or the insured. The private sector, and specifically private EMS agencies, are however obliged to assist uninsured patients in an emergency, stabilise their condition and transfer them to the closest appropriate facility to provide further care [29].

This study focuses on one of the largest national private EMS agencies in South Africa. The specific period was selected, as this particular EMS provider had changed data capturing and storage systems, and this was the most extended timeframe on a single database that could be searched for the data required. The inclusion criteria were patients with pre-hospital CA, who received CPR, from birth to 18 years, treated by EMS personnel of the selected national private EMS agency. None of the pre-hospital CA paediatric patients was excluded. Pre-hospital paediatric CA was defined as the cessation of circulation of blood, due to absent or ineffective cardiac mechanical activity in a person aged birth to 18 years which occurred before or during pre-hospital medical care and transportation to a hospital.

Data Collection

Ethical clearance was obtained from the University of the Witwatersrand (WITS) (Ref: M150231) and the participating EMS agency (Ref: UNIV-2016-0017). A data analyst employed by the EMS agency was assigned to assist the researchers in ensuring the confidentiality of patient data. The role of the data analyst was to search the database, retrieve all paediatric cases with pre-hospital CA who received CPR and to anonymise the patient records. The researcher then worked through each case, to ensure that it met the stated inclusion criteria (n=195). The researchers then captured the anonymised case records on a Microsoft ExcelTM spreadsheet using the Utstein-style as reference. The following data were captured: non-modifiable factors of CA (gender, age, aetiology and initial rhythm), modifiable factors of CA (witnessed

arrest, bystander CPR, airway management, vascular access, defibrillation, drug administration, EMS arrival time, EMS scene time and EMS transport time), and the primary outcome of pre-hospital ROSC.

Data Analysis

Data were analysed using SPSS (Version 22) (IBM, Armonk, NY, USA) [30]. Descriptive statistics (frequencies, percentages, means, standard deviations, medians and interquartile ranges) were computed to describe the non-modifiable and modifiable factors of CA. Logistic regression models were used to estimate the association between non-modifiable and modifiable factors of CA on ROSC. In analysing ROSC, odds ratio estimates were determined unadjusted.

Results

There were 195 paediatric cases of pre-hospital CA. With regard to non-modifiable factors of CA (see Table 1), the majority of paediatric patients were males (n=122; 62.6%), 57 of the cases were in the 6-12-year age group (29.2%), and 130 of the cases were categorised as medical emergencies as opposed to being caused by trauma (66.7%). The most common aetiologies were drowning (n=62; 31.8%), unknown medical reasons (n=28; 14.4%), motor vehicle/motorbike collisions (n=27; 13.8%), sudden infant death syndrome (SIDS) (as listed by the EMS provider) (n=25; 12.8%), and pedestrian-vehicle collisions (n=21; 10.8%). The most common initial rhythm was asystole (n=104; 53.4%), followed by 43 cases of pulseless electrical activity (PEA) (20.5%).

Table 1: Description of non-modifiable factors of cardiac arrest (n=195)

<u>Factor</u>	<u>n (%)</u>
Gender:	
Male	122 (62.6%)
Female	73 (37.4%)
Age:	
Infants (0-12 months)	54 (27.7%)
1-2 years	19 (9.7%)
3-5 years	29 (14.9%)
6-12 years	57 (29.2%)
13-18 years	36 (18.5%)
Case description:	
Medical	130 (66.7%)

Trauma	65 (33.3%)
Aetiology:	
Drowning	62 (31.8%)
Motor vehicle/Motorbike collision	27 (13.8%)
Pedestrian-vehicle collision	21 (10.8%)
Birth Emergency	6 (3.1%)
Sudden infant death syndrome	25 (12.8%)
Aspiration/Choking	7 (3.6%)
Gunshot wound	6 (3.1%)
Stab wound	2 (1.0%)
Assault	2 (1.0%)
Electrocution/lightning	1 (0.5%)
Poisoning/Overdose	4 (2.1%)
Hanging	1 (0.5%)
Other trauma	3 (1.5%)
Unknown medical	28 (14.4%)
Initial Rhythm:	
Asystole	104 (53.3%)
Pulseless electrical activity	43 (22.1%)
Shockable	8 (4.1%)
Not in cardiac arrest on arrival	40 (20.5%)

Regarding modifiable factors (see Table 2), 42 (21.5%) of the cases were EMS witnessed. Bystander CPR prior to EMS arrival was initiated in 87 cases (44.6%). Rescue breaths were provided by the EMS without an advanced airway in 142 instances (74%) and via an advanced airway in 152 cases (77.9%). In this study, the case files did not distinguish between the different types of advanced airways, so this would include endotracheal and supraglottic airways. Intravenous (IV) access was the most common vascular access (n=113; 58.5%), as opposed to intraosseous (IO) access (n=56; 29.0%). Twenty-two of the cases were defibrillated (11.3%), and the most common drugs administered were adrenaline (n=151; 77.8%) and amiodarone (n=8; 4.1%). Eighty-eight of the paediatric patients were transported to the emergency department (45.1%), and ROSC was achieved in 42 cases (21.5%). On average, EMS arrival time (from receipt of call to arrival on scene) ranged from 0 to 38 minutes, but data was markedly non-normally distributed with a median (interquartile range) of 1 minute (0 minutes . 4 minutes). EMS time spent on scene ranged from 0 to 59 minutes, with a median (interquartile range) of 23 minutes (10 minutes . 40 minutes). EMS transport time ranged from 0 to 106 minutes, with a median (interquartile range) of 10 minutes (5 minutes . 17 minutes). The total case

time ranged from 0 to 106 minutes, with a median (interquartile range) of 33 minutes (20 minutes . 51 minutes).

Table 2: Description of modifiable factors of cardiac arrest (n=195)

<u>Factor</u>	<u>n (%)</u>
EMS witnessed arrest	42 (21.5%)
Bystander CPR (prior to EMS arrival)	87 (44.6%)
Airway management	
Rescue breaths (without advanced airway)	142 (74%)
Advanced airway	152 (77.9%)
Vascular access:	
Intravenous access	113 (58.5%)
Intraosseous access	56 (29.0%)
None	24 (12.4%)
Defibrillation	22 (11.3%)
Drug administration	
IV Adrenaline	151 (77.8%)
Amiodarone	8 (4.1%)
Transported to emergency department	88 (45.1%)
Return of spontaneous circulation	42 (21.5%)
<u>Factor</u>	<u>Median (IQR)</u>
Emergency medical service	
Arrival time (minutes)	1.00 (0.00-4.00)
Scene time (minutes)	23.00 (10.00-40.00)
Transport time (minutes)	10.00 (5.00-17.00)
Total case time (minutes)	33.00 (20.00-51.00)

When considering odds ratios (OR) (see Table 3) with regard to non-modifiable factors of CA, only initial rhythm had a statistically significant effect on ROSC. Among pre-hospital paediatric patients, those diagnosed with an initial rhythm of PEA were almost five times as likely to achieve ROSC (OR=4.56; 95% CI 1.97-10.64) compared with the odds of asystole. The odds ratios, although not statistically significant, further indicated that an initial shockable rhythms (OR=2.33; 95% CI 0.43-12.81) and those not in CA on arrival (OR=2.33; 95% CI 0.43-12.81) were twice as likely to result in ROSC compared to asystole. Also, females had a higher rate of

ROSC, compared to males (OR=0.66; 95% CI 0.33-1.32). Paediatric patients aged 6-12 years old had the highest rate of ROSC (OR=1.47; 95% CI 0.71-3.03), and those aged 13-18 years had the lowest rate (OR=0.68; 95% CI 0.26-1.77), compared with the odds of infants. Trauma cases had a slightly higher rate of ROSC than medical cases (OR=1.14; 95% CI 0.56-2.34), with paediatrics in vehicle collisions having the highest rate of ROSC (OR=1.76; 95% CI 0.73-4.20), and those involved in drowning having the lowest rate (OR=0.29; 95% CI 0.06-1.40), compared to other respiratory aetiologies, viz. aspiration/choking and SIDS.

With regard to modifiable factors of CA, bystander CPR prior to EMS arrival was the only one with any statistically significant effect on ROSC, with paediatrics who had received bystander CPR almost twice as likely to achieve ROSC (OR=2.16; 95% CI 1.08-4.33). Other non-modifiable factors, although not statistically significant, showed that EMS witnessed arrest increased chances of ROSC (OR=1.18; 95% CI 0.53-2.66). With regard to airway management, advanced airways showed increased chances of ROSC (OR=1.21; 95% CI 0.53-2.76), while rescue breaths (without advanced airways) (OR=0.70; 95% CI 0.32-1.49) did not. If vascular access and defibrillation occurred, the paediatric patients' chance of ROSC decreased. Neither IV nor IO access ostensibly had much effect on ROSC, and the only drug that showed a slight increase in ROSC was amiodarone (OR=1.26; 95% CI 0.24-6.47). Following the initial call, EMS arrival time of 5-10 minutes (OR=0.71; 95% CI 0.28-6.54) or more than 10 minutes (OR=0.66; 95% CI 0.09-4.53), had lower odds of ROSC compared with the odds of EMS arrival time of under 5 minutes. On-scene time of 10-34 minutes (OR=0.57; 95% CI 0.20-1.63) and longer than 35 minutes (OR=0.91; 95% CI 0.44-2.06) had lower odds of ROSC compared with the odds of EMS scene time of under 10 minutes. Finally, transport time greater than 10-34 minutes (OR=0.85; 95% CI 0.12-5.71) had lower odds than transport time of more than 35 minutes (OR=1.69; 95% CI 0.26-10.97) compared with the odds of transport time of under 10 minutes.

Table 3

Multivariable logistic regression model for return of spontaneous circulation

<u>Non-modifiable factors</u>	Odds ratio (95th CI)
Gender (reference: female)	

Male	0.66 (0.33, 1.32)
Age (reference: infant [0-12 months])	
1-2 years	1.34 (0.45, 3.97)
3-5 years	0.94 (0.36, 2.49)
6-12 years	1.47 (0.71, 3.03)
13-18 years	0.68 (0.26, 1.77)
Case description (reference: medical)	
Trauma	1.14 (0.56, 2.34)
Aetiology (reference: respiratory [aspiration/choking, SIDS])	
Drowning	0.29 (0.06, 1.40)
Vehicle collision (MVA/MBA, PVA)	1.76 (0.73, 4.20)
Other (poisoning/OD, birth emergency, gunshot wound, unknown medical, stab wound, other trauma, electrocution/lightning, assault, hanging)	1.43 (0.56, 3.70)
Initial rhythm (Asystole)	
Shockable	2.33 (0.43, 12.81)
PEA	4.58 (1.97, 10.64)**
Not in CA on EMS arrival	2.33 (0.93, 5.87)
<u>Modifiable Factors</u>	
EMS witnessed arrest	1.18 (0.53, 2.66)
Bystander CPR (prior to EMS arrival)	2.16 (1.08, 4.33)*
Airway management (reference: none)	
Rescue breaths	0.70 (0.32, 1.49)
Advanced airway	1.21 (0.53, 2.76)
Vascular access (reference: none)	
Intravenous access	0.69 (0.31, 1.56)
Intraosseous access	0.64 (0.20, 2.03)
Defibrillation	0.54 (0.151, 1.92)
Drug administration (reference: none)	
Adrenaline	0.61 (0.28, 1.34)
Amiodarone	1.26 (0.24, 6.47)
Emergency medical service	
Arrival time (reference: <5min)	
5-10 min	0.71 (0.28, 6.54)
>10 min	0.66 (0.09, 4.53)
Scene time (reference: <10min)	
10-34 min	0.57 (0.20, 1.63)
>35 min	0.91 (0.44, 2.06)
Transport time (reference: <10 min)	

10-34min	0.85 (0.12, 5.71)
>35 min	1.69 (0.26, 10.97)

* Statistically significant at the .05 level (2-tailed).

** Statistically significant at the .01 level (2-tailed).

Discussion

This appears to be the first study to explore the association between non-modifiable (gender, age, aetiology and initial rhythm) and modifiable (witnessed arrest, bystander CPR, airway management, vascular access, defibrillation, drug administration, EMS arrival time, EMS scene time, and EMS transport time) factors of paediatric CA and its association with ROSC in the African context.

Only two variables were statistically significant. An initial rhythm of PEA (OR=4.58; 95% CI 1.97-10.64; P<0.001) was the only non-modifiable factor, and bystander CPR (OR=2.16; 95% CI 1.08-4.33; P<0.05) the only modifiable factor, significantly associated with ROSC in this study.

In line with international research, the most common initial rhythms in this study sample were asystole followed by PEA [31,32]. Research links an initial rhythm of asystole with the lowest possibility of ROSC and as the least likely to attain favourable one-month survival [33]. However, in this study population there was an increased percentage of PEA as initial rhythm [34,35] and an increased achievement of ROSC [33] compared to what is documented in international studies in general.

Paediatric CA victims who received bystander CPR were almost twice as likely to result in ROSC. It is well established that CPR performance increases survival and improves outcomes [5,32], and in this study population, the association with ROSC was similar to that reported in international literature [10,11,15]. This may be because it is a private South African EMS agency, which provides services to patients with higher socio-economic status. As a result, families may have higher education levels, which is directly linked to increased levels of bystander CPR performance [9,18]. The most common reason given by bystanders for not providing life-saving CPR is that they are in a panic or are afraid that they will incorrectly

perform CPR [36]. The American Heart Association (AHA) [37] recommends conventional CPR (with rescue breaths) for paediatrics, regardless of the CA aetiology, as compression-only CPR is of little value where hypoxia is the cause of CA. Thus, citizens should be taught conventional CPR (with rescue breaths) and be aware that it is more beneficial to try to at least do compressions than to do nothing at all [5]. Furthermore, much improvement has been documented in bystander CPR rates with dispatcher-assisted CPR, although this has not been adequately researched in the paediatric population [38, 40] and there appears to be no data on dispatcher-assisted CPR in the African context.

Although not statistically significant, the study results showed negative associations with ROSC and the non-modifiable factors of male gender, paediatric ages of 13-18 years, medical cases and drowning. A unique finding in this study was that drowning was the most common aetiology of paediatric CA. Globally the AHA [41] ascribes most cases of CA in paediatrics to the traumatic insult following motor vehicle collisions, akin to the Medical Research Council of South Africa, which similarly ascribes this as the main cause of CA in paediatrics in South Africa [42]. Furthermore, drowning was associated with the least chance of ROSC, which is congruent to other published findings [13,14].

With regard to modifiable factors, although not statistically significant, there was a positive association with ROSC and the placement of an advanced airway, and the administration of amiodarone. The positive association between advanced airway management and ROSC is contrary to international findings, which link this factor with decreased paediatric survival [7,16,43]. In fact, EMS success with endotracheal intubation in a child is variable with many complications; it often leads to interruptions in compressions and delayed transfer of the patient to the hospital [7], and therefore this factor would need further exploration with a larger dataset.

Finally, EMS arrival time of under 5 minutes, scene time of under 10 minutes and transport time of more than 35 minutes was positively associated with ROSC in this study, although not statistically significant. EMS arrival time of under 10 minutes is strived for by most EMS providers, as its association with improved outcomes is undisputable [7,16]. However, scene time and transport time is debated in the

literature. An on-scene time of 10-35 minutes [7,27] and scene time of less than 10 minutes [44] are both associated with improved outcomes, but depends largely on the aetiology and condition of the paediatric patient. Similarly, shorter transport times are associated with improved outcomes [45] but longer transport times may not lead to poorer outcomes [46].

Limitations

A retrospective descriptive audit has the inherent limitation of not being able to prove causality. Moreover, the major limitation of this study was the small study population. A larger sample would have been able to demonstrate more reliable associations between the non-modifiable and modifiable factors of CA and ROSC. Also, this study was only conducted in one private EMS agency in South Africa, and therefore study results are not generalisable to the greater paediatric population of South Africa. Finally, most of the comparative studies cited emanate from developed settings, where the EMS and healthcare systems are mature and resources are substantially different compared with the South African study setting.

Conclusion

Prevention is the most effective way to avoid deaths in paediatrics [41]. This is also reflected in this study where the most common aetiology of CA is drowning. Drowning cases also have the highest probability of mortality and severe illness and injury, thus more must be done to raise public awareness of water safety. In this study, there was a significant association between initial rhythm and bystander CPR and ROSC. Bystander CPR is the only aspect that is modifiable, highlighting that more should be done to increase citizens awareness and skills in the performance of basic life support, with training initiatives targeted towards parents and those who take care of children, e.g. daycare staff, school teachers and staff. Dispatcher-assisted CPR is also a proven strategy that improves bystander CPR rates in adult patients internationally, and should therefore be studied in more detail in the African context, especially among the paediatric population. Finally, more studies in Africa with larger samples are suggested since very few statistically significant associations were found between the non-modifiable and modifiable associations of CA and ROSC in this study.

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Extended Literature Review

Introduction

In this chapter, the main variables of the study will be defined, and the context of pre-hospital emergency care in South Africa will be discussed. The pathophysiology and resuscitation of cardiac arrest (CA) in paediatrics will also be explained and the main non-modifiable factors of CA (gender, age, aetiology and initial rhythm) and modifiable factors of CA (witnessed arrest, bystander cardiopulmonary resuscitation (CPR), airway management, vascular access, defibrillation, drug administration, emergency medical service (EMS) arrival time, EMS scene time, and EMS transport time) will be presented. Finally, the relationship between these factors and return of spontaneous circulation (ROSC) will be highlighted.

Search Strategy

The literature review was conducted with the assistance of a subject librarian. Dissertations, theses and databases (EBSCOHost [Academic Search Premier, CAB Abstracts, CINAHL, E-journals, ERIC, Health Source Premium, MasterFILE Premier, MEDLINE, Pre-CINAHL, PsycARTICLES, PsycINFO, SociINDEX with Full Text, Humanities International Complete, Academic Search Complete and Education Research Complete], ScienceDirect, Scopus, Web of Science, PubMed, SAePublications and Google Scholar) were considered. The keywords were combined in varying sequences. The keywords included (out AND "of" AND hospital) AND (paediatric* OR pediatric*) AND (cardiac resus* or resus*), and were searched in the categories of "All" or "Title" or "Abstract" or "Author-Supplied Abstract" or "Keywords".

Pre-hospital Paediatric Resuscitation

In order to discuss pre-hospital paediatric resuscitation, each of the concepts are defined and discussed in more detail.

Emergency care personnel in the pre-hospital EMS setting of South Africa is defined as persons registered under Section 17 of the Health Professions Act, 1974 [1], who hold a valid qualification accredited by the Health Professions Council of South Africa (HPCSA). Emergency care personnel are required to register with the

HPCSA, Professional Board for Emergency Care to be allowed to provide treatment to citizens of South Africa [1,2].

A **paediatric patient** is defined as a person between birth and puberty, and a person who has not attained maturity or the age of legal majority [3], who requires medical attention, care or treatment [4].

Resuscitation is defined as the process of sustaining the vital functions of a person in respiratory or cardiac failure while reviving him or her by using techniques of artificial respiration and cardiac massage, correcting acid-base imbalance, and treating the cause of failure+[5]. The focus of this study is on CA and resuscitation.

Emergency Medical Services in South Africa

Health care is a fundamental human right and no one may be refused emergency medical treatment, as stipulated in Section 27 in The Bill of Rights of the Constitution of South Africa [6]. South Africa has a two-tiered health care system comprising a public sector and private sector. The public sector provides health care for all South African citizens as government funded. The private sector, on the other hand, is not accessible for all but is limited to the individual's ability to pay for health care services, either privately or through medical funds and insurances. The private sector, and specifically private EMS agencies, are however obliged to assist uninsured patients in an emergency, stabilise their condition and transfer them to the nearest appropriate medical facility that would be able to continue care [7,8].

The EMS in South Africa functions in the same two-tiered system and is guided by the following Acts: National Health Act, 61 of 2003; Health Professions Act, 56 of 1974; Mental Health Care Act, 17 of 2002; Medicines and related substances Act, 101 of 1965; Promotion of Access to Information Act, 2 of 2000 and the Protection of Information Act, 84 of 1992.

According to the Health Professions Act, 56 of 1974, all health care practitioners who practice the professions of Dental Assisting, Dental Therapy & Oral Hygiene; Dietetics and Nutrition; **Emergency Care**; Environmental Health; Medical and Dental (and medical science); Medical Technology; Occupational Therapy, Medical Orthotics, Prosthetics & Arts Therapy; Optometry & Dispensing Opticians;

Physiotherapy, Podiatry and Biokinetics; Psychology; Radiography & Clinical Technology and Speech-Language and Hearing Professions, are obliged to register with the HPCSA. The HPCSA and each of the 12 professional boards regulate the standards of education and training, and set and maintain standards of ethical and professional practice [9].

The Professional Board for Emergency Care (PBEC) is constituted in terms of the Regulations relating to the constitution of the Professional Board for Emergency Care contained in Regulation No. R 1254 of 28 November 2008. The professions that are registered under this board include Basic Ambulance Assistants (BAA), Ambulance Emergency Assistants (ANA), Operational Emergency Care Orderly (OECO), Paramedics, Emergency Care Technicians (ECT) and Emergency Care Practitioners (ECP) [10].

In the private sector, there are additional requirements to treat medical aid or insured patients for financial compensation. Private EMS companies are additionally guided by the Medical Schemes Act No. 131 of 1998. The Board of Healthcare Funders (BHF) came into existence as a legal obligation from the Medical Schemes Act No. 131 of 1998, and aims to ensure the sustainability of the healthcare sector by enabling medical schemes, manage care organisations and administrators to provide accessible, affordable, quality healthcare to their medical scheme members+ [11]. Private EMS need to register for a practice code number from the BHF. The practice code number is a legal requirement for the process of reimbursement of a claim to either a medical scheme member or service provider [12]. In order to receive this number, the EMS company is inspected by the South African Private Ambulance and Emergency Services Association (SAPAESA), which is contracted by the BHF and does the inspection in accordance with the current BHF norms and standards document [13]. As a non-profit organisation, SAPAESA aims to constantly improve the standards of pre-hospital care. In 1994, SAPAESA went into close partnership with the BHF to establish minimum inspection and accreditation criteria for ambulance services to register with the BHF. To date, this organisation is recognised by the government and other private EMS companies as a representative body for the South African Private EMS [14].

Although the public and private EMS sectors usually work together to provide emergency medical care in the two-tiered health system, the public sector primarily treats those without medical aid or the uninsured, and the private sector treats those with medical aid or the insured [15,16]. The two largest national private EMS companies in South Africa are Netcare 911 and ER24. These companies have the most significant market share of medical aid schemes as clients, and both have a national footprint with linkages to specific private hospital groups [17,18]. This study focused on national private EMS companies.

Emergency Medical Services Education and Training in South Africa

The BAA, ANA and Critical Care Assistant (CCA) are vocational training courses or short courses that were introduced in 1985. These short courses follow on each other and are provided by accredited government and private training facilities [19]. The 3-week BAA course produces entry-level EMS practitioners, the 12-week ANA course produces mid-level EMS practitioners, and the 4-month CCA course (with an additional 5 months of clinical roadwork) produces advanced EMS practitioners (who are registered as paramedics).

In 1987, EMS training was introduced into the higher education band, with the introduction of a 3-year national diploma (National Qualification Framework [NQF] Level 7) at Universities of Technology (registered as a paramedic). Then in 2001, EMS training was increased to a Bachelor of Technology Degree (NQF Level 8), which produced practitioners who could operate independently at an increased level of clinical care (registered as ECP with an enhanced scope of practice compared to a paramedic) [19].

Between 2004 and 2006, the HPCSA reviewed the BAA, ANA and CCA short courses and higher education qualifications (National Diploma and B.Tech EMS). They introduced a 2-year formal qualification for the mid-level EMS worker at NQF Level 6, named an Emergency Care Technician (ECT), and a Bachelors, Masters and Doctorate degree in Emergency Medical Care [19]. In 2016, the HPCSA began to explore a 1-year formal qualification for the entry-level EMS worker at NQF Level

5, [20] named an emergency care assistant (ECA) which will be implemented in 2018/2019 [21. 23].

The HPCSA is now in the process of discontinuing the existing BAA, AEA and CCA short courses, which have remained relatively unchanged since 1985. These are not compliant with the existing training of the National Qualification Framework (NQF) and are mal-aligned to the education and training of other health professionals [19].

With regard to all the different qualifications currently registered on the roll, there remains a basic principle of three levels of care in the pre-hospital setting: 1) Basic life support (BLS) as basic non-invasive care, 2) Intermediate Life Support (ILS) with minimal invasive care and treatment protocols of certain acute medical and traumatic emergencies, and 3) Advanced Life Support (ALS) with a broad scope of practice and protocols for the treatment of acute medical and traumatic emergencies.

Paediatric Cardiac Arrest

CA in the paediatric patient can be sudden, or the last event in a trauma or disease process contributing to respiratory failure or shock. CA is when the pump in the circulation system fails and results in a discontinuation of blood flow [24].

Respiratory failure is the primary cause of CA in paediatrics. Respiratory failure is either hypoxemic or hypercapnic. Hypoxemic respiratory failure results in the decrease of PaO₂, and hypercapnic respiratory failure causes an increase of PaCO₂ [25].

Shock is a state in which oxygen delivery to organ tissue is inadequate. This might be due to a number of reasons like hypovolemia, sepsis, cardiac origin, and hypoxia. Any medical condition or traumatic insult that causes a disruption in the balance between cellular oxygen supply and demand will lead to a state of shock. In a state of shock, cellular metabolism moves from aerobic to anaerobic metabolism which causes an increase in metabolic acidosis and eventually cellular death and/or CA [24]. Paediatric myocardial tissue has increased glycogen stores available, which enables the myocardial tissue to perform better in anaerobic metabolism as compared to adult myocardial tissue [26].

The body always compensates when in a state of shock, aiming to maintain homeostasis. This is done through various mechanisms to preserve adequate tissue perfusion for as long as possible. These mechanisms include increasing vascular volume by redistributing intracellular and interstitial fluid to the vascular space, sympathetic response decreasing urine output and maintaining cardiac output for end-organ perfusion, shunting blood from non-vital organs, increasing oxygen transfer from haemoglobin by fever acidosis, and increasing 2,3-diphosphoglycerate. Hypotension in the paediatric patient is a late sign of shock and signifies decompensatory shock when the body is no longer able to compensate for the increased state of acidosis, and death soon follows [24,26].

Paediatric Cardiac Arrest Resuscitation

The aim of CA resuscitation in paediatrics is to recognise and treat reversible causes (respiratory failure and shock) as soon as possible, to restore cardiac and pulmonary function, and ensure survival to hospital discharge with good neurological outcomes [27]. Factors that influence the outcomes of paediatric patients include pre-existing medical condition/s, the environment in which the arrest occurred, the initial rhythm, the duration of no-flow time, and the quality of life-supporting interventions provided during and after resuscitation [27. 30]. EMS practitioners are in a position to provide life-saving interventions as they are the first healthcare professionals on the scene. They are able to assess, manage and monitor the paediatric patient properly both before and during transfer from the site of ill health or injury, to the nearest healthcare facility.

Treating the pulseless non-breathing paediatric patient has come a long way. In the early 80s, research with regard to paediatrics was limited and paediatric outcomes were dismal as a result [27,31]. Paediatrics was considered the orphan of EMS, until 1988 when the first paediatric resuscitation guidelines, Pediatric Advanced Life Support (PALS) were developed by the American Heart Association (AHA). Consequently, survival to hospital discharge, most with favourable neurologic outcomes, has improved [27].

In 1992, principal resuscitation organisations (including the Resuscitation Council of Southern Africa) established a forum named the International Liaison Committee on

Resuscitation (ILCOR) with the mission to promote, disseminate and advocate international implementation of evidence-informed resuscitation and first aid, using transparent evaluation and consensus summary of scientific data [32]. In 2000, ILCOR, in collaboration with AHA, produced the first international CPR guidelines, which are reviewed every five years [32,33]. In 2006, the AHA introduced the chain of survival with the most important link being the prevention of injury or arrest [34]. The links that follow on this are Early recognition of CA and effective CPR, Early activation of EMS or ERS and Early advanced life support (ALS) [34]. This chain of survival emphasises that prevention is the most effective way to avoid deaths in paediatrics [34]. Then, with regard to resuscitation, the C-A-B (CPR, Airway, Breathing) sequence is applied in paediatrics [35].

With current treatment guidelines, resuscitating a paediatric patient can be categorised into four phases [24]. The first phase is the pre-arrest or protect phase. The aim of this phase is to prevent the paediatric patient from experiencing pulseless CA. In this phase it is essential to recognise and treat respiratory failure and shock as soon as possible, to prevent CA. The EMS practitioner or bystander should initiate near continuous chest compressions and rescue breaths [27,34,35]. Additionally, the EMS practitioner will secure an airway, provide oxygen, assist with breathing and support the circulatory system as needed. He will perform a differential diagnosis and provide treatment as needed.

The next phase is the arrest or no-flow phase as an untreated CA. The most important factor in this phase is the prompt recognition of CA with the initiation of BLS. BLS is a specific treatment protocol for CA, which involves CPR and early defibrillation with an automated external defibrillator (AED), as well as basic airway and breathing manoeuvres [36].

The third phase is the CPR or low-flow phase. The goal of CPR is to optimise coronary and cerebral perfusion and blood flow to critical organs. Effective CPR consists of pushing hard, pushing fast, allowing full chest recoil, minimising interruptions and not over-ventilating [27]. During CPR, cardiac output and pulmonary blood flow are 10-25% of that during normal sinus rhythm. Consequently, much less ventilation is necessary for adequate gas exchange. Studies show that over-ventilation during CPR, which substantially compromises venous return and

cardiac output, is common. This tendency, as well as interruptions during chest compressions to provide airway management and rescue breathing, often contribute to reduced survival outcomes [27,37. 43]. During this phase, the EMS practitioner will attempt to treat reversible causes, perform ALS skills, provide a definitive advanced airway, administer cardiac supporting medication like adrenaline and amiodarone or lignocane. Medication might also include the selective ad hoc use of Calcium Chloride, Magnesium, Sodium Bicarbonate and Dextrose as indicated to treat specific reversible causes. The EMS practitioner will also plan the transportation of the paediatric patient to a healthcare facility for further treatment [24,36].

The fourth phase is the post-resuscitation phase following ROSC. This is a high-risk period for secondary brain injury, ventricular arrhythmias, systemic ischemia, and persistent precipitating pathology. Due to the unnatural pathophysiological state created by achieving ROSC, treatment in this phase is complex. As the EMS practitioner is mostly involved in the acute short-term treatment, attention is thus focussed on managing oxygenation, ventilation, circulation, blood pressure, temperature, and blood glucose. [24,27,36].

Every phase of resuscitation is unique to the circumstances and the clinical picture of the paediatric patient. The EMS practitioner continuously has to adapt the treatment plan to what is required in the specific phase. Despite best practice guidelines and protocols, a large percentage of pre-hospital CA paediatrics do not survive. Even ROSC does not always mean that there will be long-term survival with a good neurological outcome [44. 46]. However, there are non-modifiable and modifiable factors that have a direct influence on achieving ROSC, and these will be highlighted in the text to follow.

Non-modifiable Factors

In the following sections, non-modifiable factors (gender, age, aetiology and initial rhythm) are discussed and the relationship between these factors and ROSC are highlighted.

Gender

Studies show that most pre-hospital CA occurs in males under one year of age [47. 49].

Age

Survival following CA is the greatest in paediatrics [50. 52], but even then survival is less than 10%, of whom many have unfavourable neurologic outcomes [52. 56]. In a recent large retrospective study in the USA, paediatric ages were stratified, and it was found that infants had the lowest survival rate (3.7%), compared to children (9.8%) and adolescents (16.3%) [53]. Other studies also found that older age of paediatrics was associated with improved survival [52]. The poorer survival outcomes in infants may, in part, be explained by infants having a smaller physiologic reserve; larger vulnerability to CA; greater susceptibility to hypoxia-induced pre-hospital CA [47,57]; having the highest incidence rates of CA [47]; having less witnessed events; CA most often occurring at night time; having lower rates of initial recorded shockable heart rhythms; CA often being due to unknown causes (i.e. Sudden Infant Death Syndrome [SIDS], congenital cardiac diseases); having the highest rate of %coop and run+responses (shortest scene time and fewer interventions); and being the most likely recipients of resuscitative efforts despite having been dead for some time [47,53].

Aetiology

The aetiology for CA varies significantly between different age groups, with the rate of non-cardiac causes increasing with increasing age [47]. The AHA [36] ascribes most cases of CA to traumatic insult resulting from motor vehicle collisions. In an Australian study of 349 children treated by Helicopter Emergency Medical Services (HEMS), the most common aetiology was trauma-related injury (80%). Of these, the majority were falls (33%), motor vehicle incidents (30%) and sports injuries (14%). Drowning (12%) was the most common non-traumatic mechanism [58]. These findings were comparable to the aetiologies reported by HEMS paediatric patients in the Netherlands [59].

Motor vehicle incidents and drowning have the highest probability of mortality and severe illness and injury, thus focus should be laid on enforcing the use of car restraint devices and pool safety [27,58].

With regard to infants, most CA events take place in the hospital setting. A study conducted in the USA indicated that only 3.7% of reported neonatal deaths were reported from the out-of-hospital setting [60]. CA in neonates and infants can be ascribed to premature birth complications, congenital abnormalities, respiratory failure, asphyxia, infection, malignancy, shock and/or anaemia, and in some cases injury or neglect [60,61]. The leading cause of CA among infants is SIDS, which is a catastrophic event in paediatric patients under one year of age with an unknown cause. The syndrome peaks between 2-4 months [62].

Initial rhythm

Ventricular Fibrillation (VF) and Ventricular Tachycardia (VT), also known as malignant ventricular dysrhythmias, are considered the best initial rhythms or shockable rhythms in CA patients, and are associated with better outcomes than the asystole or pulseless electrical activity (PEA) rhythms [27,50]. Shockable rhythms like VF and VT are observed in less than 10% of paediatric cases and are more common in adolescents and paediatric patients with congenital heart disease [52]. The most predominant presenting rhythm in paediatrics is asystole followed by PEA [56].

When ventricular dysrhythmias occur, it is more common in children and adolescents than in infants. Ventricular dysrhythmias are often the general cause of CA, but subsequent ventricular dysrhythmias may occur during resuscitation efforts of an initial rhythm of asystole or PEA [27,63]. Paediatric survival rates increased with more than 30% when the initial rhythm was shockable, as compared to those with shockable rhythms occurring later during the resuscitation [47,50,64].

Modifiable Factors

In this section, modifiable factors of CA (witnessed arrest, bystander CPR, airway management, vascular access, defibrillation, drug administration, EMS arrival time, EMS scene time, and EMS transport time) are discussed and the relationship between these factors and ROSC are highlighted.

Witnessed arrest and bystander CPR

Approximately 31% of paediatric pre-hospital CA are witnessed, and of these only about 30% receive bystander CPR [48,49,65]. This is an unfortunate finding when you consider that bystander CPR increases the likelihood of survival by 2- or 3-fold [29,66]. In fact, most studies around the world show improved outcomes from bystander CPR [67]. The most common reason given by bystanders for not providing life-saving CPR is that they are in a panic or are afraid that they will perform CPR incorrectly [68].

Research has shown that it is most often family members who provide bystander CPR in comparison to strangers [69], but that this is directly linked to higher parental education level [47,69]. In general, persons with a higher education level were more likely to perform bystander CPR [47,69].

In retrospective studies of CA with adults, it was found that the outcome of bystander-initiated CPR with either chest compressions alone or chest compressions with rescue breathing have similar outcomes [70,71]. In fact, the AHA recommends compression-only CPR for adults with single providers. However, this is not the case in paediatrics, where the cause of CA is often asphyxial in nature [72]. Thus, in pre-hospital CA from non-cardiac causes, conventional CPR (with rescue breathing) is preferable, while in arrests from cardiac causes, either chest compressions alone or conventional CPR are equally effective [72]. However, the AHA [36] guidelines state that it is preferable to use conventional CPR rather than chest compressions alone, regardless of the CA aetiology.

Airway Management

Airway management aims to achieve adequate tissue oxygenation, ventilation and limit aspiration of gastric contents. Airway management includes the following interventions: suctioning, bag-valve-mask ventilation, supraglottic airways, continuous positive airway pressure/bilevel positive airway pressure, advanced airways (endotracheal intubation, combitube, King LT, Laryngeal Mask Airway, oesophageal obturator) and surgical airways [73]. After initial bag-valve-mask ventilation, 80% of patients receive either a supraglottic airway or endotracheal intubation [74].

A meta-analysis showed that in adults with pre-hospital CA, endotracheal intubation had significantly higher odds of ROSC, survival to hospital admission and neurologically intact survival, as compared to supraglottic airways [74]. However, paediatrics are often the recipients of difficult or failed endotracheal intubation in the pre-hospital setting [75,76] as it requires a unique skill set and equipment to perform these procedures in an effective, timely and safe manner on patients whose anatomy varies according to age and size [73,77]. In fact, paramedics success with endotracheal intubation in a child is variable [53,55,78,79] with many complications [53,78,80, 82] that lead to interruptions in compressions [53,83,84] and delayed transfer of the patient to the hospital [53,85,86].

A large study conducted in North America showed that pre-hospital airway management in paediatrics was infrequently performed, and when performed, success rates were lowest in patients with CA and those aged 1-12 months [73]. Additionally, a sizeable Pan-Asian study showed that advanced airway management was associated with decreased survival of paediatrics (OR 0.73; 95% CI 0.67-0.80) [87,88]. In fact, it was found that bag-valve-mask ventilation was associated with higher survival to hospital discharge compared to both endotracheal intubation (0.39 [95% CI 0.26-0.59]), and supraglottic airways (0.32 [95% CI 0.12-0.84]) in non-traumatic pre-hospital CA. However, Barker and Weatherall [58] argue that distance between the site and nearest treatment facility may have a bearing on the benefit of endotracheal intubation, as intubation and ventilation theoretically improve control of oxygenation and carbon dioxide, and prevent aspiration of gastric contents, which is critical in the case of long transport periods [58].

Vascular Access

Parenteral pre-hospital drugs are typically administered via the intravenous (IV) route. However, IV access may not always be practical or possible in all patients, especially in the case of paediatric patients or the event of CA; then, intraosseous (IO) access is recommended [89]. IO access has been recommended in paediatric advanced life support since 1988 [90], but research still shows that paediatrics are less likely to have vascular access established before arrival at the hospital compared with adults [75]. A recent retrospective study in North America showed that attempts at placing IV and/or IO catheters or needles were associated with

improved survival [53]. Furthermore, research has found that IO access can be established faster and has a higher first-time success rate than IV access [91]; serum drug concentrations are equivalent to those administered through peripheral IV lines [92]; and IO first approach is equivalent to IV first approach based on ROSC at the time of arrival at the emergency department [89].

Defibrillation

In paediatrics, shockable rhythms like VF and VT are observed in less than 10% of cases and are more common in adolescents, paediatric patients with congenital heart disease [52] or other cardiovascular causes [93]. Thus, the treatment of choice is effective CPR, as most CA in paediatrics is due to asphyxia and/shock [27,94].

For VF and pulseless VT, rapid determination of electrocardiogram (ECG) rhythm and prompt defibrillation when appropriate are critical, as CPR without defibrillation is futile for paediatrics in VF [53]. The goal of defibrillation is return of an organised electrical rhythm with pulse. When AEDs are used within 3 minutes of adult witnessed VF, long-term survival can occur in >70% of cases. With each minute of delay thereafter, the mortality rate increases by 7%-10% [27,95,96]. An initial rhythm of VF has improved survival rates and neurologic outcomes compared to asystole or PEA (93)]. A large Pan-Asia study confirmed increased chances of survival for paediatrics with pre-hospital defibrillation (OR 2.31; 95%CI 1.96-2.72) (69)].

Drug Administration

Medication most commonly used for resuscitation in paediatrics are inopressors (adrenaline) and antiarrhythmics (amiodarone or lidocaine). No single medication has been shown to improve survival outcomes from paediatric CA [27,51,97], but the two most commonly used are adrenaline and amiodarone.

Adrenaline increases systemic and peripheral vascular resistance, which increases diastolic blood pressure, ultimately increasing coronary and cerebral perfusion pressure and blood flow during effective CPR [27,98,99]. Adrenaline also increases myocardial contractility and heart rate, relaxes smooth muscle and increases the vigour and intensity of VF, all of which increase the likelihood of ROSC and successful defibrillation [27,50,99,100]. The recommended dosing interval is every 3-

5 minutes, but less frequent adrenaline dosing has been linked to improved survival [101]. Similarly, standard-dose (0.01-0.02 mg/kg) adrenaline versus high-dose (0.05-0.2 mg/kg) adrenaline may increase initial ROSC, but prospective, retrospective and randomised clinical trials indicate that high-dose adrenaline does not improve survival and may be associated with worse neurologic outcomes [99,100,102, 104].

VF or pulseless VT are the most treatable initial rhythms due to responsiveness to shock [105], but frequently recur and become resistant to shock [106]. Antiarrhythmic drugs, amiodarone and lidocaine, are often used to encourage conversion of VF or pulseless VT to a perfusing rhythm and prevent recurrences [105,106]. The 2015 ILCOR treatment recommendation suggest to either use lignocaine or amiodarone for shock resistant VF and pulseless VT [107]. There was no difference between amiodarone or lidocaine administration when considering survival to discharge or neurologic outcomes [105], although both were associated with better outcomes when given one or both of the medications compared to no treatment [106].

EMS arrival time, scene time and transport time

Treatment of life-threatening events at the scene of the incident rather than waiting until arrival at the hospital has been shown to reduce mortality [108,109]. Results from a Pan-Asian study showed that EMS arrival time of less than or equal to 8 minutes was associated with improved outcomes (OR 1.52; 95% CI 1.35-1.71) [87], while a North American study showed that on-scene time of 10-35 minutes was associated with increased survival (10.2%), compared to the more than 35 minutes group (6.9%), and the under 10 minutes group (5.3%) [53].

Spending more time at the scene to provide treatment may improve the quality of CPR [53,110,111] which enhances survival rates and outcomes [53,112]. The duration of compressions has been studied extensively and researchers have found that mortality and neurological disability vary directly with compression duration; 1-15 minutes having the best outcome, followed by 16-35 minutes, but there was still positive outcomes in compression lasting more than 35 minutes [113]. Matsuyama, et al. [114] were also of the opinion that the patient could still benefit from prolonged CPR durations of >30 minutes. This was further studied by Matos, et al. [115], who divided paediatric patients into aetiology of arrest (cardiac or respiratory). These authors found that rates of survival for respiratory-failure induced CA declined

exponentially after 15 minutes, but for cardiac-failure induced CA there were still good outcomes with compressions lasting up to one hour. Also, shorter transport times are associated with improved outcomes [116], but longer transport times do not lead to poorer outcomes [117].

Conclusion

In this chapter, the main variables of the study were defined, the context of pre-hospital emergency care in South Africa was discussed, the pathophysiology and resuscitation of CA in paediatrics were explained, and the main non-modifiable factors of CA (gender, age, aetiology and initial rhythm) and modifiable factors of CA (witnessed arrest, bystander CPR, airway management, vascular access, defibrillation, drug administration, EMS arrival time, EMS scene time, and EMS transport time) were addressed. Finally, the relationship between these factors and ROSC were highlighted.

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Appendix 1 – Approved research protocol

1.1 Introduction

International Emergency Medical Service (EMS) researchers have evaluated paediatric pre-hospital practices to establish a baseline database aimed at improving paediatric resuscitation, however, no similar study has been conducted in Africa [1]. According to the South African *2006 Saving Children's Report*, 21.5% of the 1073 paediatric deaths were attributed to factors relating to emergency care upon admission, whereas 6% of the 2223 pre-hospital paediatric deaths were attributed to transport-related factors. These findings resulted in a national appeal for EMS to: *“Develop national norms for pre-transfer assessment, management and monitoring of sick children, as well as for ambulance waiting times and in-transit monitoring and management”* [2].

The EMS provides out-of-hospital acute medical care for the ill or injured, including paediatrics, and transfers these patients to the nearest appropriate healthcare facility [3]. Akin to the South African healthcare system, the EMS operates in both the public and the private sector. The private sector serves less than 20% of the South African population, who have access to more than 70% of the country's finances and resources. In general, private EMS providers are replete with the resources required to provide state of the art pre-hospital care, while their public EMS provider counterparts, who serve the bulk of the population, often operate with insufficient personnel and scant resources to manage patients efficiently [3].

Management and care of paediatric patients require emergency medical personnel to adapt to various special situations. Paediatric patients present unique challenges with regard to differing age-related ranges of normal vital signs, medication dosages that must be calculated according to weight, and the obvious limitations in communication with the young paediatric patient [4].

Cardiac arrest (CA) is a catastrophic event where the mechanical ability of the myocardium fails to circulate blood, resulting in acidosis and, ultimately, cellular death. CA is a critically time-sensitive event . the sooner treatment can be provided

to restore respiratory and cardiac function and the return of spontaneous circulation (ROSC), the better the long-term outcomes. CA in the paediatric patient is usually secondary to progressive respiratory failure or shock, which leads to bradycardia, hypotension and, if prolonged, CA [5]. The most common electrocardiography (ECG) finding in paediatric CA is asystole and pulseless idioventricular electrical activity, followed by ventricular fibrillation and pulseless ventricular tachycardia [6].

During ventricular fibrillation without cardiopulmonary resuscitation (CPR), chances of survival decrease by 7-10% per minute. If CPR is performed, the survival rate decreases at a more gradual rate of 3-4% per minute. To improve the likelihood of survival, ventricular fibrillation must be treated as soon as possible with defibrillation [7]. Lay rescuers with rapid access to an Automated External Defibrillator (AED) are easily able to manage ventricular fibrillation quickly and effectively to facilitate improved patient outcomes. In the chain of survival, Advanced Life Support (ALS) skills are performed following or in conjunction with Basic Life Support (BLS) skills. Although ALS skills are traditionally recommended to augment desirable outcomes, little evidence supports their impact on survival. Early CPR and defibrillation, as part of the BLS skill set, are essential interventions in treating CA [5]. ALS skills encompass advanced procedures for airway management, intravenous or intraosseous fluid administration, administration of resuscitation drugs, and investigation and treatment of potentially reversible causes of CA [8].

CA in the paediatric patient started to receive its due scientific attention in the mid-80s with the first American Heart Association (AHA) paediatric resuscitation guidelines. The guidelines were released in 1986 and aimed to improve paediatric outcomes via the provision of evidence-based care. The guidelines have since been reviewed and updated six times [9]. Various basic and advanced life support interventions are recommended by these guidelines to inform evidence-based treatment of the paediatric patient with the aim of restoring and maintaining cardiopulmonary function [10]. The ultimate long-term goal is to ensure survival until hospital discharge, without any unfavourable neurological outcomes [5].

Studies conducted in North America and Canada revealed that pre-hospital paediatric CA survival is only about 10% [11]. Research conducted in the last 15

years has found that the most critical non-modifiable determinants of survival include older age, an initial shockable rhythm and witnessed arrest, while the most important modifiable determinants include bystander CPR, early arrival of EMS, level of EMS training and early defibrillation. A recent large observational study using the Resuscitation Outcomes Consortium CA database from 11 North American regions, from 2005 to 2012, compared paediatric survival according to on-scene times (<10, 10 to 35, and >35 min) and found that survival was highest in the 10 to 35 minutes on-scene time group. Furthermore, the study established that older age and intravenous or intraosseous fluid administration was associated with increased survival. Placement of advanced airways had no association with survival, and the administration of resuscitation drugs was associated with decreased survival [9]. This may be because resuscitation drugs are only administered with prolonged CA, which decreases survival in itself [12].

Health professionals generally spend more time resuscitating a paediatric patient than an adult patient even though evidence suggests that longer resuscitation has no improved outcome. In a normothermic patient, irreversible brain damage occurs in 4-5 minutes from the onset of CA. The anticipated discomfort when facing the family of the demised patient appears to be a significant contributor in prolonged resuscitation attempts [13]. Despite best practice guidelines and published protocols, a large percentage of paediatric pre-hospital CA patients do not survive, and when they do, they often suffer severe neurologic debilitation [5].

The aim of this study is to conduct a retrospective audit of paediatric CA cases in a private South African EMS agency for the period of 2010/01 to 2015/01, in an attempt to establish an association between non-modifiable and modifiable factors associated with ROSC. For this study, the Utstein definition for ROSC is used, obtained from Jacobs, et al. [10]: *“ROSC is defined for all rhythms as the restoration of a spontaneous perfusing rhythm that results in more than an occasional gasp and fleeting palpable pulses”*. Non-modifiable factors include gender, age, aetiology and initial rhythm, and modifiable factors include witnessed arrest, bystander CPR, airway management, vascular access, defibrillation, drug administration, EMS arrival time, EMS scene time, and EMS transport time. Clinical outcome beyond admission to the Emergency Department will not be established in this study, however, the

primary outcome measure will be to determine whether ROSC was established upon arrival at the receiving emergency room following pre-hospital CA resuscitation [10].

1.2 Objectives

The objectives of the study are to:

- Describe modifiable and non-modifiable factors of CA care of paediatric patients in the study setting.
- Describe the association between non-modifiable factors of gender, age, aetiology and initial rhythm on ROSC.
- Describe the association between modifiable factors of witnessed arrest, bystander CPR, airway management, vascular access, defibrillation, drug administration, EMS arrival time, EMS scene time, and EMS transport time on ROSC.

1.3 Methods

1.3.1 Study Design: This study is a descriptive design based on retrospective record reviews [14].

1.3.2 Location of study: All pre-hospital paediatric CA resuscitation attempts recorded in the private South African EMS company database from all nine provinces of South Africa from 01 January 2011 to 01 January 2015 will be included for review. Approval to conduct research within the private EMS agency will be obtained.

1.3.3 Study population and inclusion criteria: The population for this study will include all pre-hospital paediatric patients in South Africa who received pre-hospital CA resuscitation from a private, national, EMS agency between 01 January 2011 to 01 January 2015. This specific time period was selected as the particular EMS provider had changed data capturing and storage systems, and this was the most extended timeframe on a single database that could be searched for the data required. The inclusion criteria were patients with pre-hospital CA from birth to 18 years, treated by EMS personnel of the selected national private EMS agency. In this study, Caroline's (4) definition of a paediatric patient will be used and includes the following stages:

neonate as the first month of life; infant as the first year of life; toddler from 1 to 2 years; preschool-aged child as 3 to 5 years; school-aged child as 6 to 12 years, and adolescent from age 13 to 18 years.

1.3.4 Exclusion Criteria:

There are no exclusion criteria. All paediatric CA victims who received CPR will be included, both trauma and medical cases.

1.4 Data capturing

A data capturing instrument which incorporates the relevant Utstein-style reporting template [10] (see Appendix 4) will be used to capture the data in accordance with the research objectives. The data fields that will be captured include: non-modifiable factors of CA (gender, age, aetiology and initial rhythm), modifiable factors of CA (witnessed arrest, bystander CPR, airway management, vascular access, defibrillation, drug administration, EMS arrival time, EMS scene time and EMS transport time), and the primary outcome of pre-hospital ROSC.

1.5 Data analysis

Data will be captured on a Microsoft Excel™ spreadsheet and analysed using SPSS Inc. [15] with the assistance of a statistician. Descriptive statistics (frequencies, percentages, means and standard deviations) will be computed to describe the non-modifiable and modifiable factors of CA. Logistic regression models will be used to estimate the association between non-modifiable and modifiable factors of CA on ROSC. In analysing ROSC, odds ratio estimates will be determined unadjusted [15].

1.6 Ethics

Ethical approval will be sought from the University of the Witwatersrand (WITS) Human Research Ethics Committee and the South African private EMS agency's Ethics Committee. The private EMS company will not be named in the research to ensure anonymity.

Data received from the South African private EMS company will be anonymised, and only relevant data as stated in 1.4 will be captured. This data will be captured on a Microsoft Excel™ spreadsheet that is password protected, and stored on a password-protected computer. Data will be deleted after the completion of this study.

1.7 Limitations

Possible limitations include that all the required fields may not be available, and that the sample may be too small to make reliable associations between the non-modifiable and modifiable factors of CA and ROSC. Also, this study will only be conducted in one private EMS agency in South Africa, and therefore study results will not be generalisable to the general paediatric population of South Africa.

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Appendix 2 – Ethic Clearance



R14/49 Mr Abraham Jacobus Coetzee

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M150231

NAME: Mr Abraham Jacobus Coetzee
(Principal Investigator)

DEPARTMENT: Emergency Medicine
Netcare 911 Emergency Medical Services

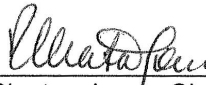
PROJECT TITLE: Audit of Prehospital Paediatric Resuscitation

DATE CONSIDERED: 27/02/2015

DECISION: Approved unconditionally

CONDITIONS:

SUPERVISOR: Martin Botha

APPROVED BY: 

Professor P Cleaton-Jones, Chairperson, HREC (Medical)

DATE OF APPROVAL: 27/07/2015

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Secretary in Room 10004, 10th floor, Senate House, University.

I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report.**



Principal Investigator Signature

28/07/2015

Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix 3 – Approval to conduct research at private emergency

RESEARCH OPERATIONS COMMITTEE FINAL APPROVAL OF RESEARCH

Approval number: UNIV-2016-0017

Mr Braam Coetzee

E mail: Braam.Coetzee@netcare.co.za ; Coetzee.aj@gmail.com

Dear Mr Coetzee

RE: AUDIT OF PRE-HOSPITAL PAEDIATRIC RESUSCITATION

The above-mentioned research was reviewed by the Research Operations Committee's delegated members and it is with pleasure that we inform you that your application to conduct this research at private emergency services, has been approved, subject to the following:

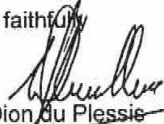
- i) Research may now commence with this FINAL APPROVAL from the Committee.
- ii) All information regarding the Company will be treated as legally privileged and confidential.
- iii) The Company's name will not be mentioned without written consent from the Committee.
- iv) All legal requirements regarding patient / participant's rights and confidentiality will be complied with.
- v) The research will be conducted in compliance with the GUIDELINES FOR GOOD PRACTICE IN THE CONDUCT OF CLINICAL TRIALS IN HUMAN PARTICIPANTS IN SOUTH AFRICA (2006)
- vi) The Company must be furnished with a STATUS REPORT on the progress of the study at least annually on 30th September irrespective of the date of approval from the Committee as well as a FINAL REPORT with reference to intention to publish and probable journals for publication, on completion of the study.
- vii) A copy of the research report will be provided to the Committee once it is finally approved by the relevant primary party or tertiary institution, or once complete or if discontinued for any reason whatsoever prior to the expected completion date.
- viii) The Company has the right to implement any recommendations from the research.



- ix) The Company reserves the right to withdraw the approval for research at any time during the process, should the research prove to be detrimental to the subjects/ Company or should the researcher not comply with the conditions of approval.
- x) APPROVAL IS VALID FOR A PERIOD OF 36 MONTHS FROM DATE OF THIS LETTER OR COMPLETION OR DISCONTINUATION OF THE TRIAL, WHICHEVER IS THE FIRST.

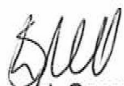
We wish you success in your research.

Yours faithfully

 13/4/2016

Prof Dion du Plessis

Full member: Research Operations Committee & Medical Practitioner evaluating research applications as per Management and Governance Policy

Shannon Nell 
Chairperson: Research Operations Committee

Date: 4/5/2016

This letter has been anonymised to ensure confidentiality in the research report. The original letter is available with author of research

Appendix 4 – Data collection template

Data Collection sheet for the cardiac arrest victim	
Study Nr:	The patient identifier will be kept, securely on a separate data sheet.
Time and day of month of Cardiac arrest	Time: : Month:
Age at the time of cardiac arrest	
Age group,	Neonate, Infant, Toddler, Preschool aged child, School aged child, Adolescent.
Weight	_____Kg
Sex	Male / Female
Presumed cause of Cardiac arrest	i.e. Sudden Infant Death Syndrome, Drowning, Falls, MVA
Trauma or Medical	Trauma or Medical
Treatment before EMS arrival	Bystander initiated CPR - Yes / No
	Defibrillation attempted with AED - Yes / No
Scene Detail	School, Residence, Street, Other_____
Time the emergency was logged with the call centre.	
Time EMS was mobile.	
Time EMS arrived on scene.	
Time EMS departed scene.	
Time EMS arrived at emergency department.	
Pre-existing medical conditions of the cardiac arrest victim	
Witnessed cardiac arrest	Yes / No
First recorded ECG Rhythm	Asystole, PEA, V-Fib
Amount of defibrillation attempts and Joule setting by EMS	
IV or IO access	
Drugs used during resuscitation	Adrenaline / Atropine / Amiodarone / Dextrose / Other_____
Airway maintained by	Jaw thrust
	Head tilt chin lift
	OP airway
	Supra-glottic airway device
	Intubation with Endotracheal Tube
	Surgical airway
	Other_____

Ventilation device / method	Mouth to Mouth
	Bag Valve Mask (assume if no other specified)
	Mechanical / Pneumatic Ventilator
Return of Spontaneous circulation	Yes / No
If ROSC, how long after CPR was initiated?	HH:MM
Cardiac arrest victim transported to hospital	Yes / No
If Yes, was CPR performed during the transportation	Yes / No
Patient handed over to Emergency room staff	With ROSC / without ROSC

Appendix 5 – Turnitin Report

774484:Article_02_12_2018.doc

X

by Abraham Coetzee

Submission date: 02-Dec-2018 08:58PM (UTC+0200)

Submission ID: 1048855696

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pediatric and adolescent resuscitation quality –
A report from the ROC epistry-cardiac arrest",
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- 14 Glenn Goodwin, Dyana Picache, Brian J Louie, Nicholas Gaeto, Tarik Zeid, Paxton P Aung, Armando Clift, Sonu Sahni. "Optimal Scene Time to Achieve Favorable Outcomes in Out-of-hospital Cardiac Arrest: How Long Is Too Long?", Cureus, 2018

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19	Bobrow, Bentley J., Tyler F. Vadeboncoeur, Lani Clark, and Vatsal Chikani. "Establishing Arizona's Statewide Cardiac Arrest Reporting and Educational Network", <i>Prehospital Emergency Care</i> , 2008. Publication	<1%
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Appendix 6 – Statistical Consultation Certificate



Private Bag X6001, Potchefstroom
South Africa 2520

Tel: 018 299-1111/2222
Web: <http://www.nwu.ac.za>

Statistical Consultation Services
Tel: +27 18 285 2016
Fax: +27 0 87 231 5294
Email: suria.ellis@nwu.ac.za

9 July 2018

Re: Study, Mr Abraham Jacobus Coetzee, student number: 774484

We hereby confirm that the Statistical Consultation Services of the North-West University analysed the data involved in the study, Audit of Prehospital Paediatric Resuscitation, of the above-mentioned student and assisted with the interpretation of the results. However, any opinion, findings or recommendations contained in this document are those of the author, and the Statistical Consultation Services of the NWU (Potchefstroom Campus) do not accept responsibility for the statistical correctness of the data reported.

Kind regards

A handwritten signature in black ink that reads 'SM Ellis'.

Prof SM Ellis (Pr. Sci. Nat)

Associate Professor: Statistical Consultation Services

Appendix 7 – Language Editing Certificate

Between lines editing

Leatitia Romero
Professional Copy-Editor, Translator and Proofreader
(BA HONS)

Cell: 083 236 4536
leatitiaromero@gmail.com
www.betweenlinesediting.co.za

19 November 2018

To whom it may concern:

I hereby confirm that I have edited the thesis of ABRAHAM JACOBUS COETZEE, entitled: “AUDIT OF PRE HOSPITAL PAEDIATRIC RESUSCITATION”. Any amendments introduced by the author or supervisor hereafter, is not covered by this confirmation. The author ultimately decided whether to accept or decline any recommendations made by the editor, and it remains the author’s responsibility at all times to confirm the accuracy and originality of the completed work.

Leatitia Romero
(Electronically sent – no signature)

Affiliations

PEG: Professional Editors Group
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